A REVISION OF *ACASTELLA SPINOSA* (SALTER 1864) WITH NOTES ON RELATED TRILOBITES

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ABSTRACT. *Acastella spinosa* (Salter 1864) and *Acastella? minor* (M'Coy 1851) are redescribed and figured. The synonymy of *A. spinosa* and *A. macrocentrus* (Reed 1925) is established. *A. spinosa* is closely compared to other species attributed to the genus. *A. prima* Tomczykowa 1962 is recorded for the first time from the late Silurian of the British Isles.

ALTHOUGH known for over a hundred years, no complete description from undistorted material of *Acastella spinosa* (Salter 1864), the type-species, has yet been published. The genus, which ranges across the Siluro–Devonian boundary, has recently become the subject of a good deal of attention from overseas workers who have, in the past eleven years, described or redescribed seven species and five subspecies. The present paper is an attempt to clarify the characteristics of the type-species, thus allowing its relationships with the newer species to be established, a study which has been accomplished with reference both to existing types and to material recently collected.

Specimens collected in the 1870s by the Geological Survey while mapping the area around Kendal, Westmorland, and recorded by Aveline *et al.* (1872, p. 14) as *Phacops downingiae* (Murchison) are redetermined as *Acastella prima* Tomczykowa, this being the first record of the species from the British Isles.

Acastella? minor (M'Coy 1851) has not been further described since the time of M'Coy. The species has not previously been figured.

The material used is located largely in the Geological Survey Museum, GSM. Other repositories are the British Museum (Natural History), BM(NH); the Sedgwick Museum, Cambridge, SM; and the Liverpool City Museum, LCM.

The symbols used in the quoted proportions throughout the text are those of Struve (1958, pp. 167–8) and are defined as follows:

A, eye length (exsag.); H, the distance from the back of the eye to the posterior border furrow of the cephalon; G, glabellar length (sag.); Gn, glabellar length (sag.) plus the sagittal dimension of the occipital ring; A/G, the large eye index; A/Gn, the small eye index.

In the notation used here for reference to the glabellar lobes and furrows, 1L, 2L, and 3L are equivalent to the preoccipital, median lateral, and anterior lateral glabellar lobes; 1S, 2S, and 3S are the corresponding furrows.

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Acastella spinosa was originally described as *Phacops* (*Acaste*) *downingiae*, var. δ, *spinosus* by Salter (1864, p. 27, text-fig. 7). The variety was based on internal moulds of a distorted cephalon (GSM 19412) and an incomplete pygidium (GSM 19414) which

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Salter considered may have been associated with the cephalon. The description was illustrated by a woodcut restoration of the cephalon.

Barrois, Pruvost, and Dubois (1922) elevated Salter's variety to specific status, referring specimens previously identified as *Dalmanites heberti* Gossellet 1888 to *Acaste spinosa* (Salter).

In 1925 Reed introduced *Acastella* as a subgenus of *Phacops* and described a new species, *A. macrocentrus*, based on an incomplete pygidium from the Upper Ludlovian of Prior's Frome, Herefordshire. He nominated (1925, p. 75) '*Acaste*' *spinosa* Salter as the type-species and gave a sub-generic diagnosis compounded from this species and from *Acastella macrocentrus*. In 1927 Reed contradicted his earlier (1925) statements, quoting as the type-species *Phacops* (*Acastella*) *macrocentrus* and giving the horizon as Wenlock Limestone (1927, p. 319). *A. macrocentrus* (Reed 1925) is shown below to be synonymous with *A. spinosa* (Salter 1864).

Acastella was subsequently classified as a genus by Delo (1935), no type-species being quoted, and as a subgenus of *Acaste* Goldfuss by R. and E. Richter (1952 and 1954). In their earlier paper (1952, p. 89) the Richters formally selected the species *spinosa* (Salter 1864) as the type-species of the subgenus and indicated the confusion caused by Reed (1927). In their later paper (1954, pp. 27–28) R. and E. Richter discussed and refigured (pl. 4, figs. 57–58) the holotype cephalon and the pygidium known to Salter. They also described and figured (p. 27, pl. 4, fig. 59) a second cephalon (GSM 19413) from the type locality, while a third, an incomplete cephalon (BM(NH) I 1397) from the Usk Inlier, Monmouthshire, was referred to *Acaste* (*Acastella*?) *sp.* (op. cit., p. 28, pl. 4, fig. 60). The latter specimen was mistakenly recorded (p. 70) as from the collections of the Geological Survey Museum. The Richters clarified the synonymy of the species listing the many mistaken references to *Acaste spinosa* which had become incorporated into the European literature since 1864. Their observations were confined to the poorly preserved material at their disposal so that a complete diagnosis and description of the species was not undertaken. Accordingly, Pillet (1959), in redescribing *Acastella rouaulti* (de Tromelin and Lebesconte 1875), Tomczykowa (1962*a*), in describing *A. prima*, and Hollard (1963) in describing *A. patula*, *A. granulosa*, and *A. jacqnemonti* were not able to make adequate comparisons with the type-species.

At the present time, full generic status is again attributed to *Acastella* by Struve (*in* Moore 1959), who includes the genus in the subfamily Acastavinae Struve 1958 (Dalmanitidae).

A. prima was described by Tomczykowa in 1962. Specimens collected and identified by Aveline *et al.* (1872) are shown to belong to this species.

Acastella? minor was originally described by M'Coy (1851, p. 161) as *Odontochile caudata* (Brongniart), var. *minor*. The generic classification of the species remains doubtful and is discussed under the section dealing with this trilobite below.

SYSTEMATIC DESCRIPTIONS

Family DALMANITIDAE Vogdes 1890

Subfamily ACASTAVINAE Struve 1958

Genus ACASTELLA Reed 1925

Acastella spinosa (Salter 1864)

Plate 24, figs. 1–8, Plate 25, figs. 6–12

1864 *Phacops* (*Acaste*) *Downingiae* Murch., var. δ, *spinosus* Salter, p. 27, text-fig. 7 (woodcut), (GSM 19412).
1925 *Phacops* (*Acastella*) *macrocentrus* Reed, pp. 73–75, pl. 11, figs. 4, 4a, (SM A 16539).
1954 *Acaste* (*Acastella*) *spinosa* (Salter 1864); R. and E. Richter, pp. 27–28, pl. 4, figs. 57 (GSM 19412), 58 (GSM 19414), 59 (GSM 19413).
1954 *Acaste* (*Acastella?*) *sp.*; R. and E. Richter, p. 28, pl. 4, fig. 60 (BM(NH) I 1397).
1963 *Acastella* cf. *spinosa* (Salter); Holland, Lawson, and Walmsley, p. 123, pl. 6, fig. 5 (BM (NH) In 57172).

For citations of *Acaste spinosa* Salter nonsynonymous with *Acastella spinosa* (Salter 1864) see R. and E. Richter 1954, pp. 23, 24, 26.

Holotype. Salter 1864, p. 27, text-fig. 7, woodcut (GSM 19412). Whitcliffe Chase, The Whitcliffe, Ludlow, Shropshire. Topmost Upper Whitcliffe Beds, uppermost Ludlovian, as defined by Holland, Lawson, and Walmsley (1963).

Diagnosis. A species of *Acastella* with the following characteristics: cephalic outline subpentangular; frontal lobe moderately convex (sag.), anteriorly rounded or very slightly angled; 3L a little larger than 2L; 1L half as wide as 2L; 2S and 3S impressed to similar depth; 2S reaching but not joining the axial furrows abaxially; occipital ring raised above glabellar side lobes; axial furrows diverging at angles between 22 and 30 degrees; preocular section of facial suture distinctly angled in front of glabella, enclosing a narrow triangular area of fixigena immediately anterior to the glabella; genal spines slender, curved; pygidium subtriangular in outline; 7 (8) axial segments; 5 pleural segments; deep furrows; border bearing 4 or 5 pairs of faint, low swellings on the internal mould; margin entire; slender caudal mucronation lying in near horizontal plane or inclined dorsally at angles of up to 60 degrees.

Description (*based on specimens preserved as internal moulds*). Cephalic outline subpentangular; in anterior view gently arched. Fixigenae postero-laterally produced into slender, curved spines.

Glabella defined by deep axial furrows diverging at angles varying between 22 and 30 degrees according to preservation, flattened specimens having a larger angle of divergence than undistorted material. Lateral profile flat across side lobes, moderately convex (sag.) across frontal lobe. Frontal lobe, in dorsal view, anteriorly gently arched, laterally rounded. In lateral profile there is a marked change in slope at the extreme anterior edge of the glabella which is seen in dorsal view to be formed by a narrow deltoid area described by the preocular section of the facial suture. Axial furrows curve gently around 2L and 3L, the glabellar width decreasing thence evenly to the posterior. The frontal lobe does not extend laterally across the course of the axial furrows. Lobe 3L is typically a little larger than 2L. 1L is about one half as wide (exsag.) as 2L. Adaxially 2L and 3L rise above the level of the median longitudinal field, a characteristic well shown on flattened material such as the holotype, while 1L tends to merge adaxially with it. 3S narrow (exsag.), moderately deep, sigmoidal, with a prominent posterior median deflection. 2S impressed to a similar depth but typically wider (exsag.), abaxially transverse, adaxially with, usually, a strong median deflection to the posterior. 2S reaches abaxially as far as the axial furrow but does not join with it. 1S deep and wide (exsag.), curving both abaxially and adaxially to the anterior. All furrows adaxially equidistant from the sagittal line. There is a tendency towards the convergence of the median extremities of

3S and 1S. A short, faint, longitudinal furrow lies on the sagittal line between the adaxial ends of 3S.

Occipital furrow abaxially deeper than 1S, less deep but remaining pronounced axially. Occipital ring fairly narrow (sag.), less wide, and with slightly greater convexity (tr.) than 1L; in lateral profile, when preserved, rising above the level of the glabellar side lobes.

Genae laterally extensive with marked border flattening. Posterior border furrow wide (exsag.) and deep, joining laterally with the border flattening. Antero-laterally the librigena passes into the doublure but reappears on the dorsal surface immediately anterior to the glabella where it forms a narrow (sag.) triangular area. The preocular section of the facial suture is dorsal intramarginal, becoming marginal at the antero-lateral edges of the glabella. Anterior to the glabella it is markedly angled, having a similar disposition to, but not as pronounced as, that of *Acastella tiro* (see R. and E. Richter 1954, pl. 5, fig. 73*d*). The postocular section of the facial suture cuts the lateral cephalic margin opposite 2S. Fixigenae postero-laterally produced into rather long, slender, curved spines, deflected outwards from their bases at an angle of some 15 degrees from the continuation of the cephalic margin projected posteriorly parallel to the sagittal line. In their appearance these spines are narrower and more elegant than those produced in *Acastella heberti heberti* (Gossellet 1888) and *A. herberti elsana* (R. and E. Richter 1954). They are, however, similar to those of *A. jacquemonti jacquemonti* Hollard 1963. The genal spines of the holotype, measured from the spine bases, are up to 2·5 mm. in length.

Eyes moderately large, subcrescentic in plan situated closer to the glabella than to the cephalic margin, extending from the middle of 1L to the confluence of 3S with the axial furrows; high ocular platform. The area, H, between the back of the eye and the posterior border furrow is moderately large: A/G, 44–51 per cent.; A/Gn, 35–44 per cent.; H/A, 20–27 per cent. In anterior profile the eye fails to reach the level of the upper surface of the glabella. Palpebral furrows well defined; palpebral lobes raised high above the adjacent palpebral areas; palpebral areas narrow (tr.), abaxially rather flat, adaxially falling steeply towards the axial furrows.

Visual surface narrow (vert.), gently convex outwards; very slightly overhanging the ocular platform; sloping outward-forwards a little less steeply than outward-backwards.

EXPLANATION OF PLATE 24

Figs. 1–8. *Acastella spinosa* (Salter 1864). 1. GSM 19412, Holotype cephalon, shell partially removed, Upper Whitcliffe Beds, The Whitcliffe, Ludlow, Shropshire, ×4. 2. GSM 102588, Cephalon, internal mould, Upper Whitcliffe Beds, quarry, 385 yd. SE. Patton Grange, SO 5908, 9530, near Much Wenlock, Shropshire, ×4. 3. GSM 102590, Cephalon, internal mould, Upper Whitcliffe Beds, locality as for fig. 2, ×4. 4. GSM 84722, Cephalon, internal mould, Perton Bone Bed, quarry near Yew Tree Inn, Prior's Frome, 3 miles ESE. Hereford, SO 5760, 3915, ×4. 5, 6. GSM 102589, Cephalon, internal mould, Upper Whitcliffe Beds, exposure on Row Lane, 504 yd. SSW. Hungerford Farm, SO 5387, 8880, Hungerford, Shropshire. 5, Dorsal view, ×4. 6, Lateral view, ×4. 7. BM(NH) I 1397, Cephalon, internal mould, Lower Llangibby Beds, quarry in wood, Llandegfydd Hill, Usk, Monmouthshire, ×4. 8. GSM 102594, Eye, internal mould, Upper Whitcliffe Beds, exposure by Diddlebury–Middlehope road, SO 5032, 8581, Diddlebury, Shropshire, ×16.

Figs. 9–11. *Acastella?* cf. *minor* (M'Coy 1851). 9–11, GSM 84723, Cephalon, internal mould, Downtonian, quarry near Yew Tree Inn, Prior's Frome, Herefordshire, 3 miles ESE. Hereford. 9, Dorsal view, ×4. 10, Lateral view, ×4. 11, Anterior view, ×4.


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11

SHERGOLD, *Acastella*

Up to about 90 closely packed lenses; dorso-ventral files carrying an approximate maximum of 6 lenses.

Hypostome and thorax unknown.

Pygidium subtriangular in outline; in posterior profile gently arched; in lateral profile, with the upper surface of the axis in the horizontal plane, the postero-lateral margins curve strongly addorsally culminating in a relatively short, slender caudal termination. This mucronation is frequently strongly curved addorsally, being typically orientated at angles varying between 30 and 60 degrees to the horizontal plane. When inclined at high angles it may rise to the level of the upper surface of the axis. It may, however, occasionally lie in a nearly horizontal plane. When viewed dorsally the spine appears to rise imperceptibly from the postero-lateral borders of the pygidium. In cross-section it has an elliptical shape. Axis strongly convex (tr.), rising above both axial furrows and pleurae; composed of seven or eight segments together with a rounded terminal piece. Axial furrows defining the first three segments diverge at a greater angle than those defining the remainder of the axis. Strong, deep, transverse furrows separate the first six segments. In lateral view the segments rise to an even height; the terminal piece is low and ends abruptly. A well-defined postaxial ridge extends from the axial termination to the spine base. Five pleurae; in posterior view moderately to strongly convex (tr.) according to preservation, sloping from a marked geniculation both to the axial furrows and border. Laterally the pleurae merge into the unfurrowed border without a marked change of slope. There is, therefore, no border furrow or flattening and the pygidium exhibits a similar condition to that of juvenile holaspides of *Acaste downingiae* (Murchison) (Shergold 1966). Pleural furrows very strong, wide (exsag.), and deep. Interpleural furrows indistinct but can generally be discerned separating the first three pleurae. Border narrow laterally, widening a little posteriorly; bearing four or five pairs of low, scarcely visible, swellings (segmental traces), set opposite the lateral end of the posterior band of each pleural segment. Such swellings characterize *Acastella granulosa* Hollard 1963, *A. patula* Hollard 1963, and *A. jacquemonti* Hollard 1963, species found in the upper part of the zone of *Monograptus uniformis* and the lower part of the *M. hercynicus* zone to the south of the Anti-Atlas Range in southern Morocco. The margin is entire, without the denticulations characterizing *A. heberti elsana* (R. and E. Richter 1954), *A. tiro* (R. and E. Richter 1954), and *A. rouaulti* (de Tromelin and Lebesconte 1875).

Remarks. The type material of *Acastella spinosa* (Salter) has been described by R. and E. Richter (1954; pp. 27–28) and further comment is unnecessary. However, it is now possible to reinterpret the specimen discussed and figured by these authors (1954; p. 28, pl. 4, fig. 6), BM(NH) I 1397, as *Acaste* (*Acastella?*) *sp.*, from Llandegfydd Hill, Usk, which appears to be comparable with material from other localities in the Welsh Borderlands now assigned to *A. spinosa* (Salter). The Richters noted that the side furrows 2S slope into the axial furrows, an observation not entirely correct as they do not open into the axial furrows. There seems, in general, to be a considerable variation in the exact position of the abaxial termination of 2S in *A. spinosa* (Salter). On specimens GSM 19412 and 102590 these furrows obviously terminate before reaching the axial furrows and in these cases it may be noted that the specimens have to some degree been flattened. On GSM 102588 and 102589 the furrows end a little nearer, while on GSM 102585 and

BM(NH) I 1397 they reach, but do not join with, the axial furrows. It may be possible therefore to relate this variation to preservation.

Acastella macrocentrus (Reed 1925) was described from an incomplete, exfoliated pygidium preserved in a limestone matrix, SM A 16539. The right pleura and antero-lateral portion of the axis are missing. On the left pleura five pleural furrows may be discerned and on the axis eight segments together with a rounded terminal piece. In lateral profile the axis, as in *Acastella spinosa* (Salter), slopes gently after segment 3 to the posterior and terminates, not markedly abruptly, before a narrow postaxial ridge. The border is narrow and there is no marked break of slope at the junction with the furrowed pleurae. Posteriorly the sides of the pygidium rise addorsally to culminate in an upturned mucronation, the end of which is broken off. The margin appears to be entire. In all these characters *A. macrocentrus* (Reed 1925) is identical with *A. spinosa* (Salter 1864) and the two species must be regarded as synonymous.

The specimen cited by Squirrell and Tucker (1960, p. 151) GSM 84722, though poorly preserved, is of some interest. It is recorded from the basal Rushall Beds of Prior's Frome, Herefordshire, the lowest member of the Downtonian in the Woolhope Inlier. Of further interest is the nature of the adhering matrix which is composed of broken shell fragments and abundant thelodont and acanthodian denticles indicating that the specimen has been derived from a bone bed. The bone bed exposed at Prior's Frome at the base of the Downtonian is equated with the Ludlow Bone Bed of South Shropshire. It is not impossible, therefore, that GSM 84722, has been derived from the uppermost bed of the Ludlovian. The specimen has been damaged, the anterior portion of the cephalon and frontal lobe, glabellar lobe 1L, the occipital ring, and the genal spines are missing, though the impressions cast by these spines can be discerned. The specimen shows the axial furrows diverging at a very similar angle to those of *A. spinosa*; the glabellar side furrows conform to a similar pattern, there being a tendency for 3S and 1S to converge adaxially; the eyes are of comparable size and are similarly positioned; the surface of the mould is without granulations. In view of the incomplete nature of this specimen (the relationship of the frontal lobe to the preocular section of the facial suture and the anterior cephalic margin is important specifically) and the similarity of the existing characteristics to *A. spinosa* (Salter) the author is of the opinion that it should be determined as *A.* cf. *spinosa* (Salter) until the discovery of further material can make a precise identification possible.

The bulk of the material of *A. spinosa* (Salter) studied is preserved as internal moulds. Material collected by the author and donated to the Geological Survey Museum has been largely prepared out so that external moulds have been lost. Fragmentary external moulds of pygidia are present in this collection but have been considered too poor to figure here. External moulds showing the complete margin of the pygidium, from which it would be desirable to obtain casts, have not been observed. An external mould of a cranidium, BM(NH) In 57172, was figured by Holland, Lawson, and Walmsley (1963, pl. 6, fig. 5) and has not been refigured here. Generally, casts from external moulds in this particular species, show little which cannot be gained from internal moulds. The furrows of both cephalon and pygidium are always wider but less deep, though they remain well incised.

Range. Upper Leintwardine Beds (terminology after Holland, Lawson, and Walmsley 1963) to the Perton Bone Bed (see below).

Distribution. Widespread in the Welsh Borderland Province (both basinal and shelf facies).

Usk: BM(NH) I 1397 is recorded from a 'Quarry in Wood, Llandegfydd Hill, Monmouthshire'. The *Acaste downingiae* (Murchison) recorded by Walmsley (1959, p. 514) may be this species. The horizon of Walmsley's specimen, and possibly also I 1397, is given as Lower Llangibby Beds (Upper Leintwardine Beds). Woolhope: Squirrell and Tucker (1960, pp. 148, 177) record *Acastella spinosa* (Salter) from the basal Lower Perton Beds (= Lower Whitcliffe Beds) and from the basal Rushall Beds (p. 151), GSM 84722. The same authors (1960, pp. 150, 177) record *A. macrocentrus* Reed from the topmost Upper Perton Beds (= Upper Whitcliffe Beds).

Ludlow: GSM 19412–14, and BM(NH) In 57172 are recorded from the Upper Whitcliffe Beds of Whitcliffe Chase, Ludlow, the type locality. Elles and Slater (1906, p. 220) record *Phacops sp.* from the *Spirifera elevata* Beds (= Uppermost Whitcliffe Beds). The locality is not specified.

Corvedale: The species has been collected both by Dr. J. Shirley and the author from a number of localities between Norton Camp (Craven Arms) and Bourton (Much Wenlock) (GSM 102585–94), in the topmost 30 or 40 ft. of the Whitcliffe Beds. It is associated with the same fauna as that occurring in the *Spirifera elevata* Beds of Elles and Slater (1906) at Ludlow.

Bishops Castle: The author has, in his possession, a pygidium, BM (NH) It 2036, from a quarry at Cwm Colebatch Farm, Cefn Einion. This locality is some 40 ft. below the horizon of the Ludlow Bone Bed, the exposed strata being equivalent to the upper part of the Llan-Wen Hill Beds (Holland 1959) at Knighton (= Upper Whitcliffe Beds).

Kerry: Earp (1938, p. 156) records *Phacops sp.* from the *Dalmanella lunata* Beds (= Upper Whitcliffe Beds). The locality is not given.

From the above survey it would appear that *Acastella spinosa* occurs earliest in the southern and south-eastern inliers in the Ludlovian shelf facies. During Upper Whitcliffian times the species migrates further to the north, spreading over a considerable area with the shallowing of the Ludlovian sea.

Relationships. In the following passage *Acastella spinosa* (Salter) is compared and contrasted with all those species which have been adequately described and placed with certainty in the genus *Acastella.*

The relationship of *A. spinosa* (Salter) to *A. prima* Tomczykowa 1962*a*. In both species the geometry of outline of the cephalon is similar, as are the courses of glabellar furrows 1S and 3S and the segmentation of the pygidium. *A. prima* differs from *A. spinosa* in the following characters: anteriorly the glabella is rounded rather than angled; the axial furrows diverge at a slightly lesser angle (20 degrees); 2S reaches and apparently joins the axial furrows laterally; true genal spines are lacking, there being instead, in the adult, short mucronate points, similar to those observed in young holaspides of *Acaste downingiae* (Murchison) (Shergold 1966); similarly the pygidium, though posteriorly distinctly angled, does not possess a caudal spine. No mention is made by Tomczykowa of the condition of the border or margin of the pygidium in respect to indications of segmentation either in the form of swellings or denticulations.

Acastella heberti heberti (Gossellet 1888) and *A. spinosa* (Salter) appear to be closely related. The dorso-ventral files of the visual surface of the former contain a maximum of six lenses, in close agreement with the maximum observed in the latter. Although R. and E. Richter (1954, p. 22) in their diagnosis of *A. heberti* give the number of pleurae in the pygidium as four, the specimen (pl. 2, fig. 28), ascribed by them to *A. h. heberti* shows distinctly five pleural furrows. It seems, therefore, that the pygidial segmentation, also, is similar to that of *A. spinosa.* There is a caudal spine in both species and likewise the pygidial margin is entire, without lateral denticulations either on shell or internal mould. The cephalon of *A. h. heberti* is, however, more distinctly pentangular in outline; the glabella is more parallel-sided, the axial furrows diverging at only 10 degrees; the frontal lobe is more strongly convex (sag.); 2S just fails to reach the axial furrows abaxially; the

pygidial border is broad and apparently smooth, no mention being made of the swellings observed in *A. spinosa* (Salter).

Acastella patula Hollard 1963 and *A. spinosa* (Salter) are similar in the following respects: the axial furrows diverge at an angle of 28 degrees in the former, 22–30 degrees in the latter; the gently angled anterior outline of the frontal lobe; the courses of the glabellar furrows; the angled nature (sag.) of the preocular section of the facial suture; the number of pleural segments in the pygidium and the possession of border swellings. The pygidium, however, of *A. patula* has a short, inflected point in place of the slender mucronation of *A. spinosa*; there is one extra segment in the axis of the pygidium and a slight flattening between the furrowed pleurae and the border; the border swellings of *A. patula* are stronger and are observed both on the shell and internal mould.

Acastella granulosa Hollard 1963 and *A. spinosa* (Salter) are quite distinct. The former possesses axial furrows diverging at 20 degrees; the glabella is less convex (sag.); 2S abaxially fails to reach the axial furrows; the occipital ring bears a median tubercle; the eye is smaller, extending (exsag.) approximately from 1S to the anterior edge of 3L; the pygidium has 6 pleural segments and 9 (10) axial segments; the test is highly granulose. Both species possess a caudal spine and have a narrow pygidial border which bears swellings, which in *A. granulosa* may be seen both on the shell and the internal mould.

A. spinosa (Salter) is equally distinct from the three subspecies of *A. jacquemonti* Hollard 1963. In these the angle of divergence of the axial furrows (20–22 degrees) is slightly less than that of *A. spinosa*; the glabella is anteriorly rounded rather than angled; the eye, where known, is smaller, in *A. j. jacquemonti* Hollard 1963 extending (exsag.) from 1S to the anterior margin of 3L; the occipital ring in *A. j. tanzideusis* Hollard 1963 bears a median tubercle; in *A. j. jacquemonti* and *A. j. levis* Hollard 1963 2S reaches abaxially as far as the axial furrows, but in *A. j. tanzidensis* fails to do so; in the pygidium each subspecies has 5 (6) pleurae and 8–10 axial segments; the border is wide and markedly flattened in *A. j. tanzideusis* and *A. j. levis* but narrow and poorly separated from the pleurae in *A. j. jacquemonti*, a condition approaching that of *A. spinosa*. In each case swellings are present on the border but to varying degrees, those of *A. j. jacquemonti* being strong and present both on the shell and internal mould, those of *A. j. tanzidensis* and *A. j. levis* being present only in the internal mould and in the latter being poorly developed. Posteriorly *A. j. jacquemonti* possesses a short, triangular, caudal point, while the mucronations of *A. j. tanzidensis* and *A. j. levis* are long spines, curving upwards in the former, straight in the latter, both of these conditions being exhibited by *A. spinosa*.

A. spinosa (Salter) can be readily distinguished from *A. heberti elsana* (R. and E. Richter 1954), *A. tiro* (R. and E. Richter 1954), and *A. rouaulti* (de Tromelin and Lebesconte 1875), as these species possess on the internal mould of the pygidium marginal denticulations, which are lateral continuations of weak swellings situated on the border. The corresponding external shell may be smooth (*A. rouaulti*) or with scarcely visible swellings, generally confined to the border. Each species also possesses a rather stout caudal mucronation and genal spines which tend to be more massive than those of *A. spinosa*.

The cephalic outline of *A. h. elsana* is more markedly pentangular; the glabella is much more parallel-sided, the axial furrows diverging at 10 degrees; the frontal lobe has a somewhat lower convexity (sag.) and the anterior outline is rounded-truncate in plan; abaxially 2S does not reach the axial furrows; the occipital ring is low (vert.); the

dorso-ventral files of the visual surface contain a maximum of 7 lenses; in the pygidium there are 4 (5) pleural segments, 7 (8) axial segments.

A. tiro has a more subtriangular cephalic outline than that of *A. spinosa*; the axial furrows diverge at about 20 degrees; abaxially 2S almost reaches the axial furrows; the occipital ring is low (vert.); the dorso-ventral files bear up to 8 lenses; the preocular section of the facial suture is quite distinctly angled (sag.) in front of the glabella; in the pygidium there are 5 pleural and 8 (9) axial segments; the border is wide and separated from the furrowed pleurae by a marked flattening.

The cephalic outline of *A. rouaulti* is similar to that of *A. spinosa*; the glabella decreases in width (tr.) less rapidly to the posterior so that the axial furrows diverge at the lesser angle of 15 degrees; the occipital ring is high (vert.), as in *A. spinosa*, and the courses of the glabellar side furrows are also closely comparable; in front of the glabella the preocular section of the facial suture is more distinctly angled; the border is wide and separated by a flattening from the furrowed pleurae; as in *A. spinosa* the caudal mucronation is inflected, at up to 30 degrees.

Acastella prima Tomczykowa 1962

Plate 25, figs. 4–5, 13–14

1872 *Phacops Downingiae*, Murch.; Aveline, Hughes and Tiddeman, p. 14.
1962 *Acastella prima* Tomczykowa, pp. 260–6, pl. 1, figs. 2–5, text-fig. 1*c*.

Material. With the exception of one specimen from the Liverpool City Museum, all the available material is from the T. McK. Hughes Collection, Geological Survey Museum. It has been obtained from the Upper Ludlovian of the Kendal and Kirkby Lonsdale regions and consists of two cranidia, TMcKH 1350, 1366; three good pygidia, LCM 60.64 ME, TMcKH 1032, 1336, and several incomplete pygidia, TMcKH 6 (two specimens), 989, 1073, 1350, 1363.

Localities.
LCM 60.64 ME, Kirkby Moor Flags, Endmoor.
TMcKH 6, 1336, 1350, 1363, 1366, Holme Scales, Hutton Bridgend, SE. of Kendal.
TMcKH 989, Killington, N. of Kirkby Lonsdale.
TMcKH 1032, Gatebeck, N. of Kirkby Lonsdale.

Remarks. The following translation from Tomczykowa (1962*a*, pp. 261–2) gives slightly more information on the species than the short English summary (p. 266) accompanying the paper.

Cephalon semicircular, glabella anteriorly broad and rounded. Axial furrows deep and narrow, diverging at 20 degrees. Frontal lobe large. Side-furrows S1 and S2 narrow and almost parallel to the occipital furrow and are the same depth as S3 which curves posteriorly and intersects the axial furrows anteriorly near the front end of the eye. Side-lobes L1 are half as wide as L2 and the latter half as wide as L3. Occipital ring narrow, medianly wider. Palpebral areas slightly inclined towards the axial furrows. The front margin of the fixigena is linear. The posterior margin is slightly convex and is sigmoidal towards the genal angle where it bears a very distinct, posteriorly directed tubercle.

Thorax composed of 11 segments. Axis nearly one-quarter of the maximum width. Axial furrows deep and narrow. Pleurae are ended in distinct tubercles.

Pygidium small and triangular. Axis narrow and conical, composed of 7 segments and does not reach the posterior margin. Axial furrows deep and narrow. Pleurae composed of 5 ribs which do not reach the edge of the pygidium, rapidly narrowing to the back. Posterior edge pointed.

Surface of carapace covered with very fine and dense granulations.

Acastella prima occurs in Poland in the upper part of the Siedlce Beds, at the top of the zone of *Monograptus formosus*. It is found only in material from the Lębork borehole, in northern Poland, and is not recorded from the Holy Cross Mountains. *Acastella spinosa* is reported (Tomczykowa, op. cit., p. 260) from the same borehole at a slightly higher stratigraphical level.

All the material from the Kendal area supports the observations of Tomczykowa. TMcKH 1350 shows the immature genal projections and TMcKH 1336 the short, inflected, node-like pygidial termination.

The margin of the pygidium of this species is entire and the border smooth. There appears to be no development of border swellings as are found in *A. spinosa*.

The salient differences between *A. prima* and *A. spinosa* are to be found in the nature of the mucronations. In the former these are in effect rudimentary projections rather than well-developed spines. Tomczykowa considers (op. cit., p. 266) that this species 'is a form standing at the boundary of two genera, i.e. *Acaste* and *Acastella*'. This statement is supported by work on *Acaste downingiae* (Murchison), where young holaspides of *A. downingiae* have genal mucronations similar in nature to those of the adult *Acastella prima* (Shergold 1966).

Acastella? minor (M'Coy 1851)

Plate 25, figs. 1–3

1851 *Phacops* (*Odontochile*) *caudata* (Brong. Sp.), var. *minor* M'Coy, p. 161.
1873 *Phacops Downingiae* Murchison; Salter, p. 177.

Material. Two exfoliated and incomplete cranidia, SM A 37195, 37142.

Lectotype (*here chosen*). The cranidium, SM A 37142. Kirkby Moor Flags, Benson Knot, near Kendal, Westmorland.

Extended Diagnosis. Cephalon ogival to subpentangular in outline; in anterior view gently arched. Axial furrows diverging anteriorly at 25 degrees. Frontal lobe moderately

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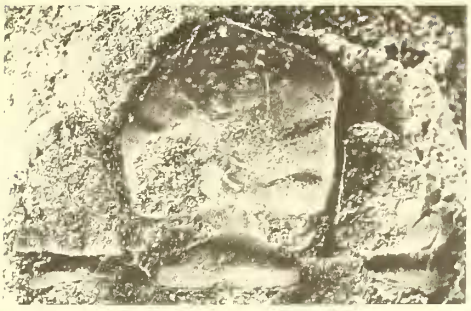
EXPLANATION OF PLATE 25

Figs. 1–3. *Acastella? minor* (M'Coy 1851). 1, 2. SM A 37195, Cranidium, exfoliated, Kirkby Moor Flags, Benson Knot, 1½ miles ENE. Kendal, Westmorland. 1, Dorsal view, ×4. 2, Lateral view, ×4. 3. SM A 37142, Lectotype cranidium, exfoliated, locality as for figs. 1, 2, dorsal view, ×4.

Figs. 4–5. *Acastella prima* Tomczykowa 1962. 4, 5. GSM TMcKH 1350, Internal mould, cranidium, Kirkby Moor Flags, Home Scales, Hutton Bridgend, 4¼ miles SE. Kendal. 4, Dorsal view, ×6. 5, Lateral view, ×6.

Figs. 6–12. *Acastella spinosa* (Salter 1864). 6. GSM 19414, Pygidium, internal mould, Upper Whitcliffe Beds, The Whitcliffe, Whitcliffe Chase, Ludlow, Shropshire, ×4. 7, 8. SM A 16539, Holotype of *A. macrocentrus* (Reed 1925), pygidium, exfoliated, Upper Ludlow, Prior's Frome, Herefordshire. 7, Dorsal view, ×4. 8, Lateral view, ×4. 9–11. GSM 102592, Pygidium, internal mould, Upper Whitcliffe Beds, exposure on Diddlebury–Middlehope road, SO 5032, 8581, 60 yd. from junction with B 4368, Diddlebury, Shropshire. 9, Dorsal view, ×4. 10, Lateral view, ×4. 11, Posterior view, ×4. 12. GSM 102591, Pygidium, internal mould, Upper Whitcliffe Beds, locality as figs. 9–11, lateral view, ×4.

Figs. 13–14. *Acastella prima* Tomczykowa 1962. 13, 14. GSM TMcKH 1336, pygidium, internal mould, Kirkby Moor Flags, Holme Scales, Hutton Bridgend, 4¼ miles SE. Kendal, Westmorland. 13, Dorsal view, ×4. 14, Oblique posterior view, ×4.



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SHERGOLD, *Acastella*